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AQUACULTURE DEVELOPMENT IN SINGAPORE

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ABSTRACT

The trend of fish production in Singapore is towards increasing contribution from marine and brackishwater aquaculture. Aquaculture production in 1986 represented 6.8% of local fish production. It is envisaged that this sector will provide about 37.5% of production by 1995. Freshwater aquaculture will focus mainly on production of ornamental fish. Production from farming of freshwater food fish is not likely to increase significantly.

Commonly farmed marine finfishes are groupers *(Epinephelus tauvina),* sea bass *(Lates calcarifer),* and golden snapper *(Lutjanus johni).* Crustaceans include prawns *(Penaeus merguiensis),* crabs *(Scylla serrata)* and mussels *(Perna viridis).* Of the freshwater finfishes, the most commonly cultured are the grass, silver and bighead carps, red tilapia *(Oreochromis niloticus* hybrid), Lampam jawa *(Puntius gonionotus),* marble goby *(Oxyleotrix marmorata)* and the snakehead *(Channa* sp.).

Aquaculture systems use a combination of floating and shore-based techniques. Earthen ponds are utilized for the culture of freshwater carps, floating netcages for marine finfish, ponds and floating netcages for marine crustaceans, and rope culture for mussels. Some research and development studies conducted presently include maturation studies to solve the problem of inconsistent supply of prawn spawners, experiments or use of dry formulated feed to do away with dependency on trash fish as main feed for grow-out marine finfish, and investigations on diseases of prawns under intensive culture.

Constraints for large-scale production of finfish seeds lie in the large tank facilities required for producing live feed; for nursery operations, time and manpower required for grading and feeding; for grow-out systems, disease prevention and control; for prawn production, inconsistent spawner supply; and for mussel production, low consumer demand.

The species with the highest potential for fanning in Singapore is the banana prawn, *Penaeus merguiensis* as its culture can be intensified and high yields can be obtained.

INTRODUCTION

Fish and fish products are popular in the diet of Singaporeans. The per capita consumption of chilled, landed marine foodfish is around 30 kg, while that of fish products like fish cakes and fish balls is about 2-3 kg. Since the introduction of floating net-cage farming in coastal waters in 1981, there has also been increasing demand for marine fish to be sold live in the restaurants.

Total supply of fish in Singapore for 1986 was 111 019 mt, with 98.7% (109 529 mt) chilled and frozen marine foodfish, and the remaining 1.3% (1490 mt) farm fresh, mainly marine foodfish and frequently sold live. Fish products, like fish cakes and fish balls, supplied for the same period was about 7800 mt.

Fresh fish supply is mainly imported from neighboring countries. In 1986, imports accounted for 80.4% (89 250 mt) of the total supply. The other source is local production, mainly from offshore trawling. In 1986, local landings accounted for 18.3% (20 279 mt) of total supply. Production from aquaculture formed only 1.3% (1490 mt).

Fish consumption in 1986 was 82 606 mt or 74.4% of total supply, giving a per capita fish consumption of 31.8 kg. Most of the produce is sold in the local market.

STATUS OF AQUACULTURE PRODUCTION

Production trend is toward increasing contribution from marine and brackishwater aquaculture. It is envisaged that by 1995, this sector will supply about 10% of total supply with about 10 000 to 14 000 mt produced annually. Production from offshore trawling is not expected to increase significantly in the future.

Freshwater aquaculture will be increasingly focused on production of ornamental fish. The export of ornamental fish is a multi-million dollar business in the Republic, with value of export reaching S $51.7 M in 1986. Production from farming of freshwater food fish is unlikely to increase significantly.

CONTRIBUTION OF AQUACULTURE TO FISH PRODUCTION

Aquaculture production in 1986 was 1490 mt contributing 6.8% local fish production of 21 769 mt. Production from marine and brackish aquaculture in 1986 was 1290 mt or 86.6% of overall aquaculture production, while that from freshwater aquaculture was only 200 mt (13.4%).

In 1986 production from marine and brackishwater aquaculture comprised 340 mt finfish, mainly groupers (*Epinephelus tauvina*), sea bass (*Lates calcarifer*), and golden snapper (*Lutjanus johni*), 332 mt crustaceans, mainly prawns (*Penaeus merguiensis*) and crabs (*Scylla serrata*), and 618 mt molluscs, mainly mussels (*Perna viridis*).

Only 200 mt of finfish was produced through freshwater aquaculture in 1986. The species comprised mainly grass carp (*Ctenopharyngodon idella*), silver carps (*Hypophthalmichthys molitrix*), bighead carps (*Aristichthys nobilis*), red tilapia (*Oreochromis niloticus* hybrid), Lampam jawa (*Puntius gonionatus*), Marble goby (*Oxyleotris marmorata*), and tomans and aruans (*Channa* spp.).

PRODUCTION TECHNIQUES

Finfish Culture

The aforementioned species are the commonly farmed finfish.

Broodstock production. There are presently five commercial marine/brackishwater hatcheries, two specializing in the production of sea bass fry/fingerlings, two in marine prawn fry production, and one in both. The finfish hatcheries combine floating and shore-based techniques; the marine prawn fry producers are also planning to start on sea bass fry production; and one floating net-cage operator is collaborating with the Government in raising sea bass fry entirely through floating net-cage methods. The government hatchery premises are used for development of techniques, and studies are carried out on the commonly farmed fish, both freshwater and marine brackishwater.

In breeding marine finfish like sea bass, the breeders are reared in net-cages. Net-cage dimensions vary: in the government floating farm specifications are 4 × 4 × 3 m whereas specifications of nets in commercial farms are 6 × 3 × 4 m to 6 × 4 × 2 m.

Brooders are kept at either 1 male to 1 female ratio, or 2 males to 1 female. Stocking density is around 4-6 kg/m^2 net area. No water management or induced maturation is practised. In the former, water exchange is through tidal currents; in the latter, natural maturation is through the lunar effect.

The breeders are fed with trash fish, consisting of small fish of low economic value, at 1-3% body weight daily during the spawning season. Predominant species is the goat fish, *Upeneus* spp. Feeding is done up to 3 times daily.

The breeders are raised from fingerlings and usually not disturbed unless for net changing. If required for placement in shore-based tanks, e.g., in induced breeding or batch treatment, fish are transported in tanks on the boat during the trip to the shore.

Gonad development and sex determination is monitored through cannulation, or for commercial operators, through visual assessment. Sexing is relatively simple in sea bass because of size dimorphism, while degree of bulging of the abdomen indicates the stage of maturity of the female. Monitoring gonad development through bioassay has been attempted by government researchers.

Very low mortality rates is observed for sea bass breeders. However, grouper breeders may suffer high mortalities caused by swollen air-bladder syndrome. The swelling of air bladder causes the affected fish to swim upside down on the water surface, leading to off-feeding and bacterial infection of the exposed portion of the ventral abdominal region. Puncturing the air bladder with a needle deflates the bladder and helps to right the fish. However, affected fish may re-inflate and revert to upside down position a few days later. Antibiotics like oxytetracycline (20 ppm) and chloramphenicol (10 ppm) can be used as a bath for the affected fish.

Main constraint to the commercial sector holding the broodstock is the vertical-integrated system of farming presently practised by hatchery operators. These people are not only involved in hatchery operations but also in farming. Hence the breeders occupy valuable space in the farm, and considerable effort has to be expended by the farmer to cover both hatchery and farming aspects simultaneously. Over time, operators may specialize in different fields.

Seed or fry production. Larvae of sea bass are reared in fiberglass tanks, either in the floating farm or on land. Tanks are either circular or rectangular, varying from 5 m^3 each in the government hatchery to 10 m^3 each in the commercial sector.

Rearing method of sea bass basically follows that developed by Thailand. Stocking density is 30-55/1. Water exchange starts at 20% daily from D_{3-5} and reaches 50% after larvae attain D_{11}.

Feeding is with rotifers (*Brachionus plicatilis*), brine shrimp (*Artemia* sp), and *Moina* (*Moina micrura*). Feeding regime in government hatchery is as follows: D_2 — rotifers at 2-3/ml; D_{3-10} — rotifers at 3-5/ml; D_{11-12} — rotifers at 5-10/ml and *Artemia* nauplii at 0.2/ml; D_{13-15} — rotifers at 5-10/ml and *Artemia* nauplii at 0.5-1/ml; D_{16-17} — *Artemia* nauplii at 0.5-1/ml; D_{18-20} — *Artemia* nauplii at 0.5-1/ml and *Moina* at 0.10-0.15/ml.

Disease is mainly due to bacterial infection. Treatment is with oxytetracycline at 2-10 ppm once every 2-3 days from D_{15-25}.

Harvesting is done by simply using hand nets.

Constraints to large-scale fry production lie in the large tank facilities required for producing the rotifers and supporting green algae *(Chlorella)* used to feed rotifers.

Nursery operation. Fry can be raised either in tanks, usually fiberglass or in floating net-boxes. In the government hatchery, tanks of 8 m^3 capacity are used. Floating net-boxes 1.8 × 1.2 × 0.9 m are used commercially at the farm site.

Stocking density in tanks starts at $5000/m^3$, with gradual thinning at different sizes of the fingerling to a final $2000/m^3$ when fingerling is 1.5-2.5 cm total length. The density applied commercially in floating net-boxes is said to be higher, varying from 9000-14 $000/m^3$ initially.

Where floating net-boxes are used, water exchange is through tidal flow. For tank culture, exchange is 30% daily.

Minced trash fish and minced grago *(Acetes* sp) are fed to fingerlings until satiation, 4-6 days. The fingerlings at this stage can also be weaned over to dry feed. This is being studied by government researchers.

The fry may be attacked by isopods especially if they are held out at sea. A formalin bath of 200 ppm for 1 hour is effective in removing the isopods but may be traumatic for the fry.

Main constraints encountered in the nursery operation are frequent grading required to minimize cannibalism during this stage and feeding the fish to satiation, operations which require time and manpower.

Grow-out production. Marine food fish raised in floating farms are held in net-cages 3 × 3 × 2-3 m or 5 × 5 × 2-3 m. The popular fishes reared are (1) finfish such as groupers, sea bass, snappers, rabbit fish, and red grouper, and (2) crustaceans such as crabs, prawns, and lobsters. A net-cage farm may rear a few types of fish and crustaceans. One farm consists of several net-cage units connected by walkways and anchored within a water space of 5000 m^2.

Freshwater carps are reared in earthen ponds, each usually 0.6-1 ha. Plankton feeding carps such as bighead and silver carps are reared in floating net-cages measuring 7 × 7 × 2 m in the reservoirs. However, rearing of fish in reservoirs are mainly for cropping down on the plankton load and not for fish production.

Freshwater ornamental fish are reared in tanks or in nets held in earthen ponds. In the case of the latter, the nets measure 2 × 2 × 1 m, with pond area ranging from 240 m^2 to 4000 m^2.

Stocking density for marine food fish in net-cages starts at 100-150/m^2 initially when the fish are only 7.5-10 cm TL, then to 44/m^2 when fish attain 12.5-15 cm TL. At harvest when fish reach market-size of 600-800 g or 30-50 cm TL, density is around 40/m^2. Water exchange in net-cages is through tidal currents. Nets are washed as frequently as monthly to remove fouling organisms like tunicates, mussels, and barnacles, and to clear it of silt. Nets with larger mesh are used as the fish grows.

Stocking density in ponds for bighead carps is around 0.13-0.17/m^2 and for common carp, 0.5/m^2 For floating net-cages, fish are stocked at 7/m^2 Red tilapia is stocked at 0.5/m^2 in ponds and around 70 m^2 in sea water under intensive experimental culture. There is very little water exchange in carp ponds. However, ponds stocked with Toman have water exchange of 25% every 2 weeks due to the use of trash fish as feed. Water exchange is also very minimal in ponds holding freshwater ornamental fish.

Marine food fish are fed with trash fish at 3-10% body weight daily. Fingerlings of 50 g are given feeds at 10% of body weight, 100 g at 8%, 300 g at 3-5%, and 500 g at 3%. Feed Conversion Ratio (FCR) is around 4-5. Government researchers are developing dry formulated feeds for groupers, sea bass, and golden snappers. FCRs obtained for dry formulated feeds are around 2.

Freshwater carps are fed with dry formulated diet, either imported or locally produced. Main ingredients are fish-meal, wheat products, rice bran, and bread left-overs. Tomans are fed with trash fish. Freshwater ornamental fish are given dry formulated feed and/or live food like *Tubifex* and *Moina.*

Fish loss during grow-out usually occurs 2-3 weeks after stocking the imported fingerlings in the net-cages out at sea. Survival can be improved considerably through sanitation — a series of 3 treatments done at various stages of shipment of the fish consignment: prior to shipment, i.e., pre-shipment, wherein fish are treated in acriflavine bath of 10 ppm for half an hour; during shipment, i.e., transhipment, antibiotics such as nitrofurazone are added to the packing water at 10 ppm; and at the time of stocking, i.e., post-shipment, fish are further treated in formalin at 100 ppm for 1 hour, followed by nitrofurazone at 10 ppm for 4 hours.

During grow-out of marine food fish, the most common disease problem encountered is that of infestation by protozoans, the most common being the ciliate *Cryptocaryon irritans.* Treatment is through a formalin bath at 200 ppm for 0.5 to 1 hr depending on the fish condition and infestation level. Vibrosis, caused by the bacteria of the *Vibrio* species, like *V. parahaemolyticus* and *V. alginolyticus,* is a common disease occurring mainly as a sequel to protozoan infestation or to physical damage sustained after importation or handling. Treatment at the earlier stages of the disease is by oral feeding of the fish with antibiotics, namely, oxytetracycline (0.5 g active ingredient/kg feed for 7 days), or chloramphenicol (0.2 g per kg feed for 4 days). Bath treatment can be attempted if the fish are off-feed: nitrofurazone at 15 ppm for 4 hours, or sulphonamides at 50 ppm active ingredients for 4 hours.

The main parasites and disease organisms in the freshwater food fish in Singapore are the ciliates. These include *Trichodina,* *Ichthyophthirius, Odinium,* and *Chilodinella* species. The copepod *Lernea* sp. is also a common parasite. Nematodes and trematodes may infest the freshwater ornamental fish.

Harvesting in floating net-cages is done simply by manually lifting the nets. For ponds, harvesting is by seining or draining the pond.

Production constraint, in the case of marine food fish, is the limited availability and high cost of fingerlings of certain popular fish species like groupers, snappers, and siganids. Sea bass is presently the only marine food fish which can be commercially bred in captivity, and the government is therefore working closely with the private sector to help farmers establish sea bass hatcheries by transferring the breeding technology to them. Government researchers are also working on the breeding of groupers and snappers.

Other constraints are the difficulty of getting local labor to work in the farm, and the limited demand for live fish in local restaurants. The government has, in certain cases allowed farms to engage foreign workers and has designated certain land on the main island and outlying islands for intensive, high-technology farming, thereby giving investors an option to establish land-based aquaculture as well. Land-based farms with higher automation will not only be able to attract local workers but will also require less workers. Farmers would have to lower production cost through better management and automation so that price of fish is within the means of ordinary consumers to buy. Exportation of live fish is also being explored by some farmers.

Shrimp/Prawn Culture

The marine prawn species cultured in Singapore is the *Penaeus merguiensis* (banana prawn).

Broodstock production. Commercial hatcheries obtain their spawners from the wild and do not hold any broodstock for maturation. A maturation program on banana prawns has been initiated by government researchers.

Seed production. Larvae are reared in tanks or canvas bags. For land-based hatcheries, larvae are usually reared in circular or rectangular fiberglass tanks of 10-15 m^3 capacity. For floating hatcheries, canvas bags of $2 \times 2 \times 1$ m are used.

Stocking density practised commercially is 100/1. Water change is limited to 30-50% daily.

Skeletonema and *Artemia* are the two organisms fed to the prawn larvae, the former from D_{2-11}, and the latter from D_{4-14}. The feeding regimes are as follows: *Skeletonema* — D_{2-8} at 10 000/ml, D_{9-11} at 5000/ml; *Artemia* nauplii - D_{4-6} at 0.5-1.5/ml, D_{7-8} at 2/ml, and D_{9-14} at 3/ml.

Infections by bacteria, causing reddening of the larval body, and by protozoans, namely, *Zoothamnium,* and fungus, namely, *Lagenidium,* are some of the common diseases encountered during larval culture. Preventive measures include good water and tank management, proper feeding regime, and periodic prophylaxis with antibiotics like oxytetracycline, and with chemicals like Cutrine-Plus®. Jelly fish infestation can also totally wipe out the culture. Treatment with 20 ppm formalin for half hour is only partially effective. However, cultures which are heavily infested have to be discarded.

Harvesting can be by hand nets or by draining the culture contents into a harvesting chamber which concentrates the fry within its screens.

Main production constraint is the present reliance on sourcing spawners from the wild. Supply is sometimes restricted to catch during spring tides. A technique of maturing the spawners under captivity is being looked into by government researchers.

Nursery operation. Fry are raised either in tanks, floating net-cages or ponds. Tanks used are usually fiberglass and of 10 m capacity. Floating net-cages are constructed of plankton nets of 0.5 mm mesh. Ponds are earthen and about 0.5 ha.

Stocking density varies from about 900/m^2 in ponds to 6000-8000/m^2 in floating net-cages. In ponds, daily water exchange is estimated at about 5-10%, being effected by tidal flows. In tanks, exchange is 80% daily, while in floating net-cages, water exchange is continuous by tidal currents.

Diseases common during this process include infestations by *Leucothrix* sp. and ciliates like *Zoothamnium* sp. on the gills, and vibrosis by *Vibrio* spp. in the haemolymph. Treatment for *Leucothrix* is through prophylaxis with copper compound (Cutrine-Plus®) at 2.8

ppm for 3 hours; *Zoothamnium* through a formalin bath at 75 ppm for 4 hours and vibrosis through an oxytetracycline bath at 10 ppm for at least 4 hours or through oral feeding at 0.75 g/kg feed for 8 days.

There are no serious constraints for the production of prawn fingerlings or juveniles.

Grow-out operation. Grow-out is commonly done in either earthen ponds or floating net-cages. A commercial company is also attempting to culture Kuruma prawn *(P. japonicus)* in raised, rubber-lined ponds of 2500 m^2 each. Experiments are conducted by government researchers on the use of 40 m^2 raceways for intensive prawn farming.

Stocking density in ponds vary from 20-30/m^2 and 300-600/m^2 in floating net-cages. In raised, lined ponds, densities are 50-60/m^2 while in raceways, the stocking density is around 600/m^2 Water management in ponds is through tidal exchanges and pumping. In raised, lined ponds, water intake is solely through pumping; resulting in 30% exchange daily- In raceways, exchange is also effected by pumping.

In all cultures, the prawns are fed with formulated dry feed, either imported or produced locally. Ingredients include fishmeal and prawn by-products. In certain cases, as in floating net-cages, prawns are also given trash fish aside from formulated dry feed.

The main loss of prawns in pond culture is due to poor water quality or plankton build-up in the pond due to difficulty in changing sufficient water daily. However, with higher stocking densities there is an expected higher incidence of disease, and prophylactic treatment is necessary.

The causative organisms are bacteria and virus, *Vibrio* spp., which causes vibrosis in the haemolymph (as in nursery stage), chitinoverous bacteria suspected to cause burnspots on the exoskeleton, and Hepatopancreas Parvo Virus (HPV) which causes lesions in the hepatopancreas of the prawn. Treatment for the first is by oxytetracycline bath at 10 ppm for 4 hr at least or through oral feeding at 0.75 ppm feed for 8 days. There is no direct treatment for the second, but oxytetracycline bath at 10 ppm for 4 hr may prevent secondary vibrosis in the haemolymph. No treatment is presently available for HPV infection. Other common diseases include muscle necrosis most likely caused by severe stress due to overcrowding and other environmental stress, white pleura disease of unknown origin, the other diseases described for the nursery stage, namely, *Leucothrix* and *Zoothamnium* infestations.

There is no serious constraint in the production of prawns in Singapore. In fact the culture of prawns has considerable potential in the Republic as it can be farmed intensively and there is tremendous local demand for prawns. More in-depth studies are, however, needed on diseases.

Mollusc Farming

Mollusc culture in Singapore is restricted to farming of green mussels *(Perna viridis).*

Broodstock production. Spats are obtained from natural spatfalls, and no attempts at broodstock management are made by the commercial farms except through retention of some percentage of the grow-out population as broodstock.

Seed production and nursery operation. Spats are usually collected on strips of old netting or nylon ropes, both usually at 2 m long. It is estimated for net strips that a good spatfall could result in the settlement of 10 million spats of 0.5 g each on each strip of rope.

No thinning is practised commercially as this has been found to be too time-consuming and labor-intensive by the farmers. Instead, the spats are allowed to thin out naturally. This, however, results in wasteful drop-out of the spats, and only an estimated 10-15% of spats attain market-size 6-8 months later. This technique can be used in areas which are good spat grounds. However, for poorer spat grounds nylon ropes and nettings are not suitable as spat collectors, and coconut coirs have been found to be better spat collectors. Government researchers have devised a rope called poly-coco for such situations. This type of rope combines both collection of spats on the coconut coir sections, and grow-out on the polyethylene main rope.

Grow-out production. Mussels are farmed on ropes suspended from rafts. Specifications of rafts vary, but all are usually rectangular with the long axis parallel to the direction of the tidal current. Ropes are usually each 2-3 m long in the water, with another 1.5 m for tying on the raft.

Ropes are suspended at 4 ropes/m^2 and are kept about 2 m off-bottom. Water exchange is by tidal flow.

Mussels are filter-feeders, feeding on plankton in the sea. At Lim Chu Kang, where commercial farming of mussels is practised, it has not been necessary to induce plankton blooms as the waters there are relatively eutrophic throughout the year.

There is no serious disease or parasites observed to date.

However, water stagnation in the farming area, leading to low dissolved oxygen in the water, and persistent rainfall resulting in lowered salinity, may at times cause localized high mortalities.

Harvesting is by manual lifting of the ropes. This process can be mechanised. Government researchers have been conducting on-site depuration trials with the mussels.

Main production constraint is not in the farming but in the low consumer demand for the product.